METHODOLOGY FOR FLOW AND SALINITY ESTIMATES IN THE SACRAMENTO-SAN JOAQUIN DELTA AND SUISUN MARSH

FIFTEENTH ANNUAL PROGRESS REPORT TO THE STATE WATER RESOURCES CONTROL BOARD IN ACCORDANCE WITH WATER RIGHT DECISION 1485, ORDER 9

JUNE 1994

CHAPTER 1

ONGOING MODEL DEVELOPMENT: DWR DELTA SIMULATION MODEL

[Editor's Note: The following report is an electronic reproduction of the first chapter from the15th annual progress report to the State Water Resources Control Board. The original text and structure of this chapter was left the same, however, the font styling and positioning of the figures within the report have been modified.]

Introduction

This year, development work on DWR's Delta Simulation Model (DWRDSM) included extending the model boundaries both in downstream and upstream directions as well as modifications to the flow submodel, DWRFLO. For more information about the model and past efforts in DWRDSM model development, the reader is referred to the 1990 through 1993 annual reports.

Model Boundary Extension

Currently, the DWRDSM network is bounded by the downstream tidal boundary at Martinez and the upstream river boundary at the confluence of the Sacramento and American rivers. However, as the need for planning and operational model studies have become more diversified, the current boundary locations may no longer be adequate. For example, the current tidal boundary at Martinez may provide boundary information for historic model studies. But for planning studies, boundary information may not be reliable or cumbersome to estimate. Relocating the tidal boundary from the interior of the estuary at Martinez to the Pacific Ocean has an added advantage of minimizing the boundary effects on areas in the vicinity of the boundary, e.g., the Suisun Marsh. The Delta Modeling Section and the Central District's Suisun Marsh Planning group have almost completed the boundary extension to Golden Gate.

There is also a need to extend the upstream river boundary currently at Sacramento (confluence of Sacramento and American rivers) to Shasta Dam. This is based on the need for temperature modeling of the water after release from the dam. Once the model boundary is extended and the network is established, a temperature routing module can be added. Then the model can be used to evaluate various reservoir release scenarios at different temperatures and water levels. After simulating the release, temperature loads beneficial for future salmon survival studies can be routed along the Sacramento River. By also accounting for temperature loads introduced by tributary inflows and agricultural return flows, simulation of reservoir releases will help us understand temperature variation along the river as the water travels downstream.

Golden Gate Boundary – The current downstream tidal boundary is at Martinez where available historic tide and salinity boundary information are adequate for model runs with historic boundary conditions. For planning model studies, however, a long-term average tide (19-year mean tide) and an estimate of salinity is used for model runs. Under these assumptions, the model can provide only average or typical information on flow and salinity conditions of the prototype. By relocating the downstream boundary to the ocean, we can use more realistic boundary information to perform studies with nonrepeating tides. This will enable us to use the model as a forecasting tool for future planning or operational studies.

a - *Hydrodynamic Module:* The model tidal boundary was extended from Martinez to the ocean at Golden Gate. The new Bay network required 128 additional channels, 86 junctions and 6 open water areas (Figure 1-1) bringing the Bay/Delta network to a total of 615 channels, 498 nodes and 19 open water areas. Hydrodynamic calibration of the Bay portion was performed using a few May 1988 tidal cycle data with the actual tidal boundary set at Golden Gate. Channel roughness coefficients between Golden Gate and Martinez were modified until the Golden Gate tide was propagated correctly, in phase and amplitude, to Martinez (Figure 1-2). The hydrodynamics module was verified by comparing model stage with measured stage at several interior Delta locations. Model results with the current boundary at Martinez were also included in the comparison and are shown in Figures 1-3 to 1-8.

To perform a full scale verification, the hydrodynamics module was verified with observed velocity and flow data. Verification results for velocity are in Figures 1-9 to 1-12 and for flow in Figures 1-13 to1-16. Results show that the boundary extension to Golden Gate caused some phase shift in simulation results when compared with those simulated from the Martinez boundary. Also, it appears that simulations with the Golden Gate boundary resulted in lower water surface elevations in the interior Delta. This could be because the model lacks a baroclinic formulation. In general, the Golden Gate boundary extension produced stage, velocity and flow simulations that are consistent with field data as well as with the unmodified model.

b- *Salinity Module:* The salinity module of DWRDSM (with the boundary at Golden Gate) was calibrated and verified for Water Years 1987 through 1990. The first year was selected as a warm-up period. To generate flow information for salinity transport, the hydrodynamic module was run with a 19-year mean tide boundary at Golden Gate. The salinity boundary was set at constant ocean salinity of 35,000 ppm TDS throughout the simulation. Then the dispersion coefficients in channels between the Golden Gate and Martinez were modified until Golden Gate salinity was correctly dispersed to Martinez. Figure 1-17 shows model salinity, dispersed from Golden Gate to Martinez, against field measured salinity. While the model results do not depict the daily salinity fluctuations due to use of the average 19-year mean tide, it generally follows the seasonal trend of salinity variations over the 1990 water year period. Salinity at some other locations beyond the current Martinez boundary, in the Suisun Marsh area such as S71, S54 and C2 at Collinsville, are shown in Figures 1-18 to 1-21. The model results may be further improved by using daily varying hydrology and boundary tide.

Shasta Dam Boundary – The required channel geometry information for the Sacramento River, from I Street to Shasta Dam, were obtained from the Hydrologic Engineering Center (HEC) office of Corps of Engineers (COE) in Davis, California. COE used a portion of the data for their HEC-5 model. Some data also were obtained from DWR, Northern District at Red Bluff, that were used in their river spawning gravel studies. One of the first steps was to reduce and align 32 aerial photos from 250 river miles from I Street to Shasta Dam. Then channel boundaries were identified along with portions of the tributaries. A Schematic network of river segments and connections was constructed by assigning numbers to channels and connections. A new model geometry (GEOM) input file was created and connected to an existing Bay/Delta file. This preliminary Shasta network has an additional 88 channels and 83 junctions bringing the total for the entire new Bay/Delta/Shasta network to 703 channels and 581 nodes. The channel geometry data should be modified, along with any necessary network adjustments, as new information becomes available.

When the GEOM input file was generated, an initial test run was made with DWRDSM's hydrodynamic module. The model run indicated super-critical flow in upstream channels of the Shasta network. After some adjustments in channel dimensions, the model still had difficulties and was able to simulate only 5 hours of a 25-hour tidal cycle. This was probably due to DWRDSM's explicit formulation (based on the method of characteristics), which could not handle rapidly varying and transitional flow in upstream reaches of the Sacramento River.

The Bay/Delta/Shasta network was then tested with the more robust DSM2 hydrodynamic model. DSM2 is discussed in Chapter 2. The DWRDSM geometry file was converted into an equivalent DSM2 file and, after making the necessary changes, DSM2 was run. The model simulated the entire tidal cycle with only minor adjustments in geometry. The only problem was the required CPU time (about 36 minutes on Sparc I and 20 minutes on Sparc II) to solve the large system of nonlinear flow equations iteratively. The CPU time was reduced to 14 minutes on Sparc II by renumbering the channels. Use of parallel processing may further reduce CPU time down to about 5 minutes per tidal cycle, the current time required by DWRDSM.

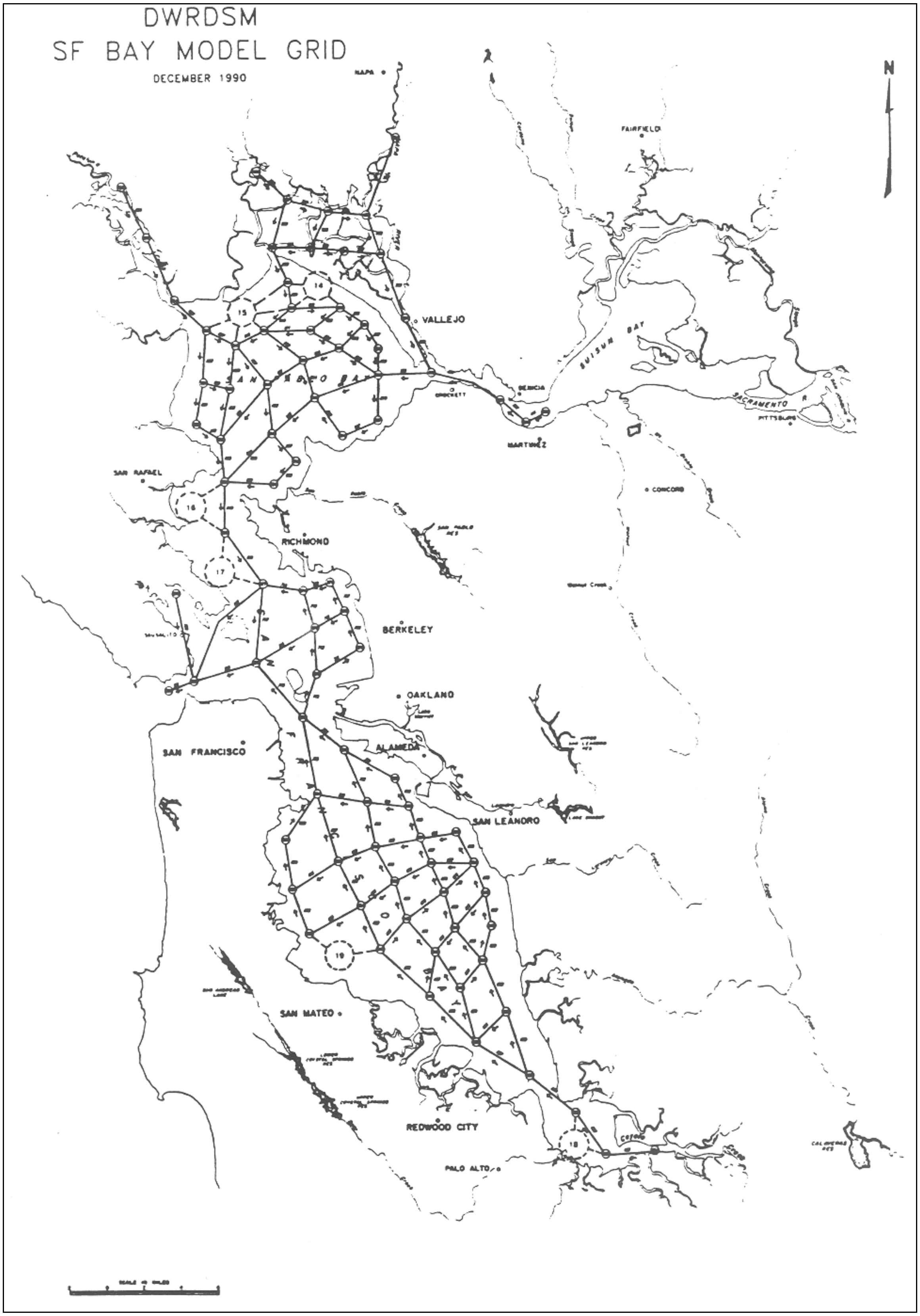


Figure 1.1: DWRDSM, San Francisco Bay Model Grid.

Figure 1-2

STAGE COMPARISON, DWRDSM VS FIELD DATA
Martinez, Channel 441

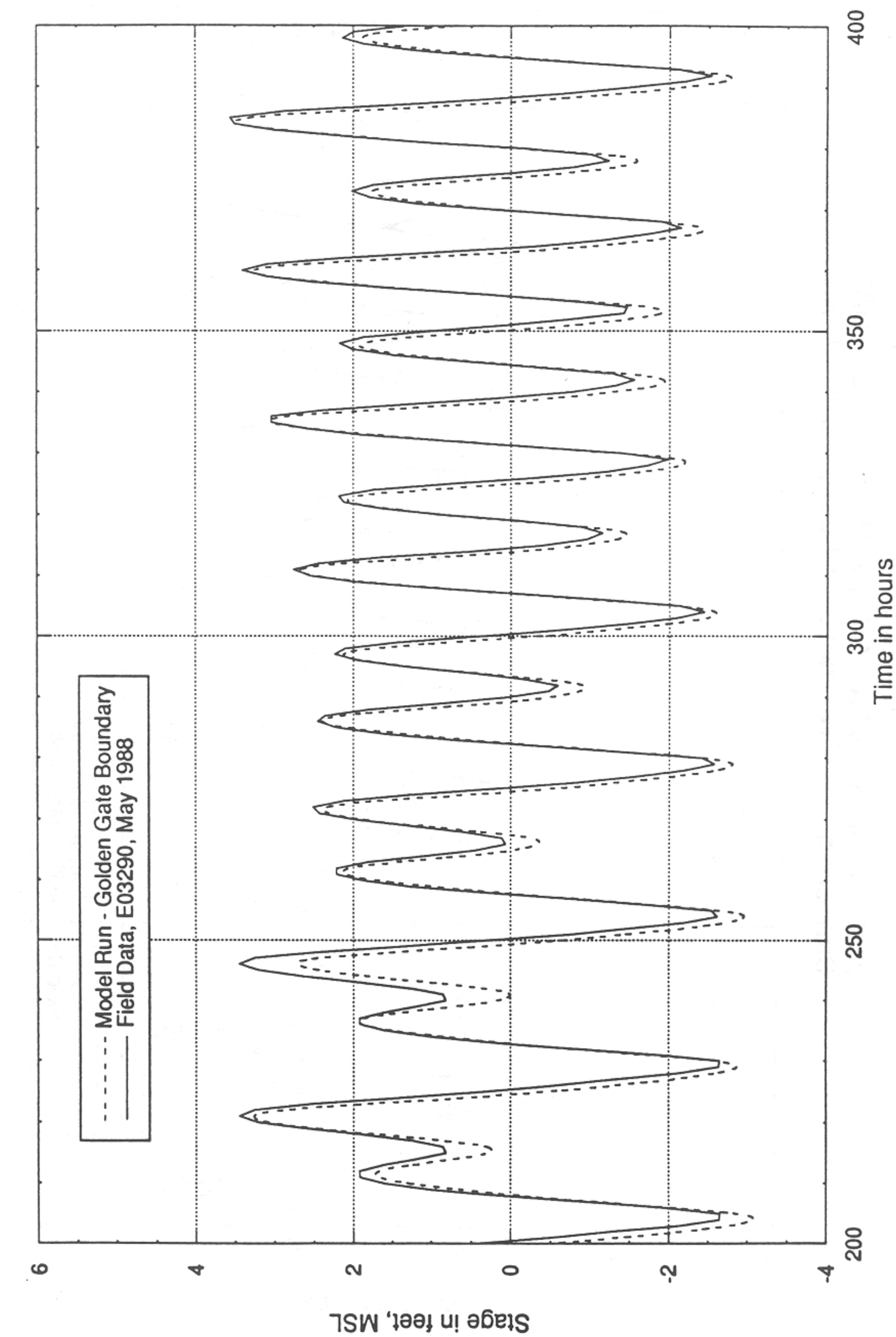


Figure 1-3

STAGE COMPARISON, DWRDSM VS FIELD DATA
San Joaquin River near Antioch, Channel 50

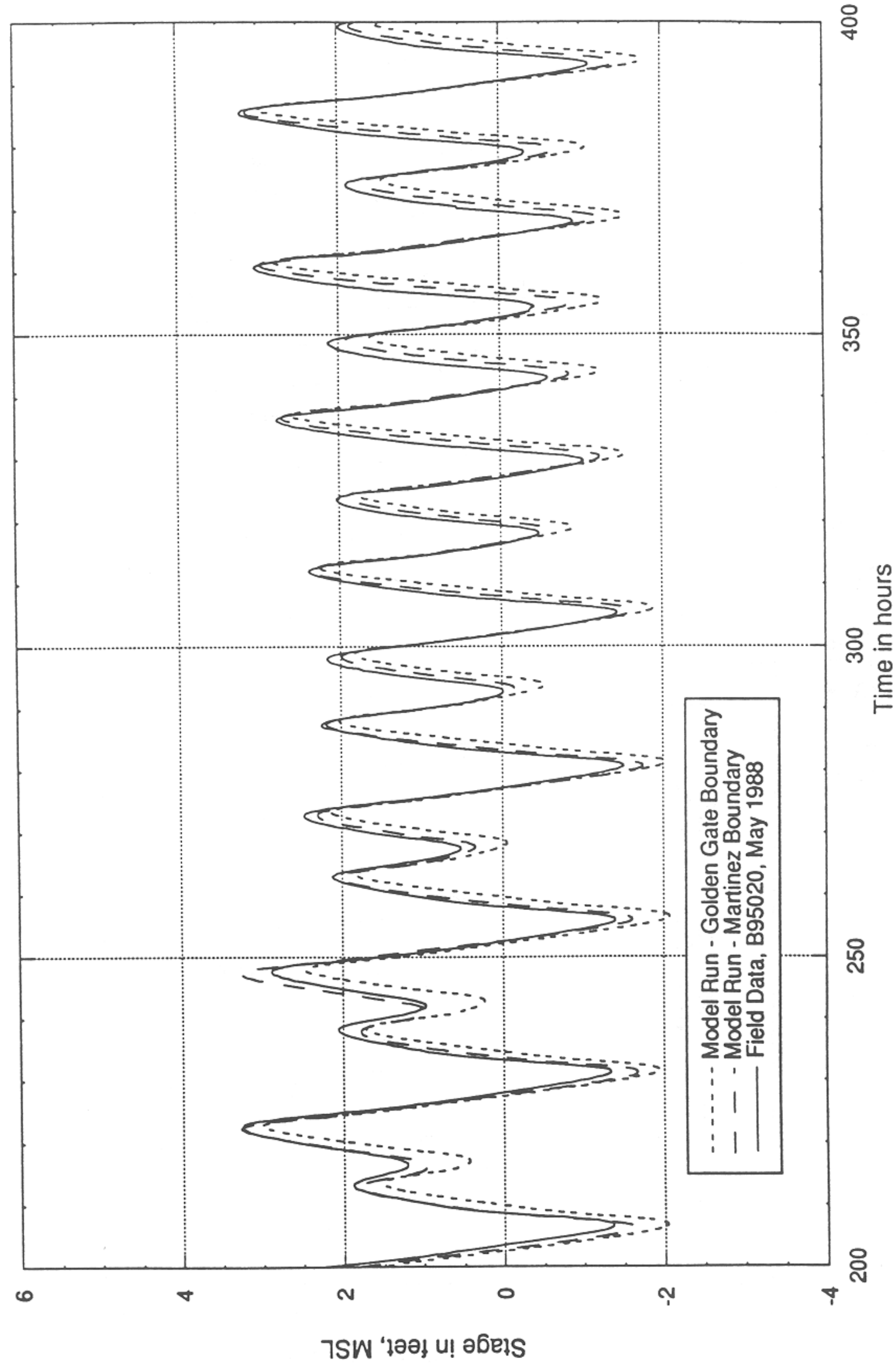


Figure 1-4

STAGE COMPARISON, DWRDSM VS FIELD DATA
Middle River near East of Union Island, Channel 125

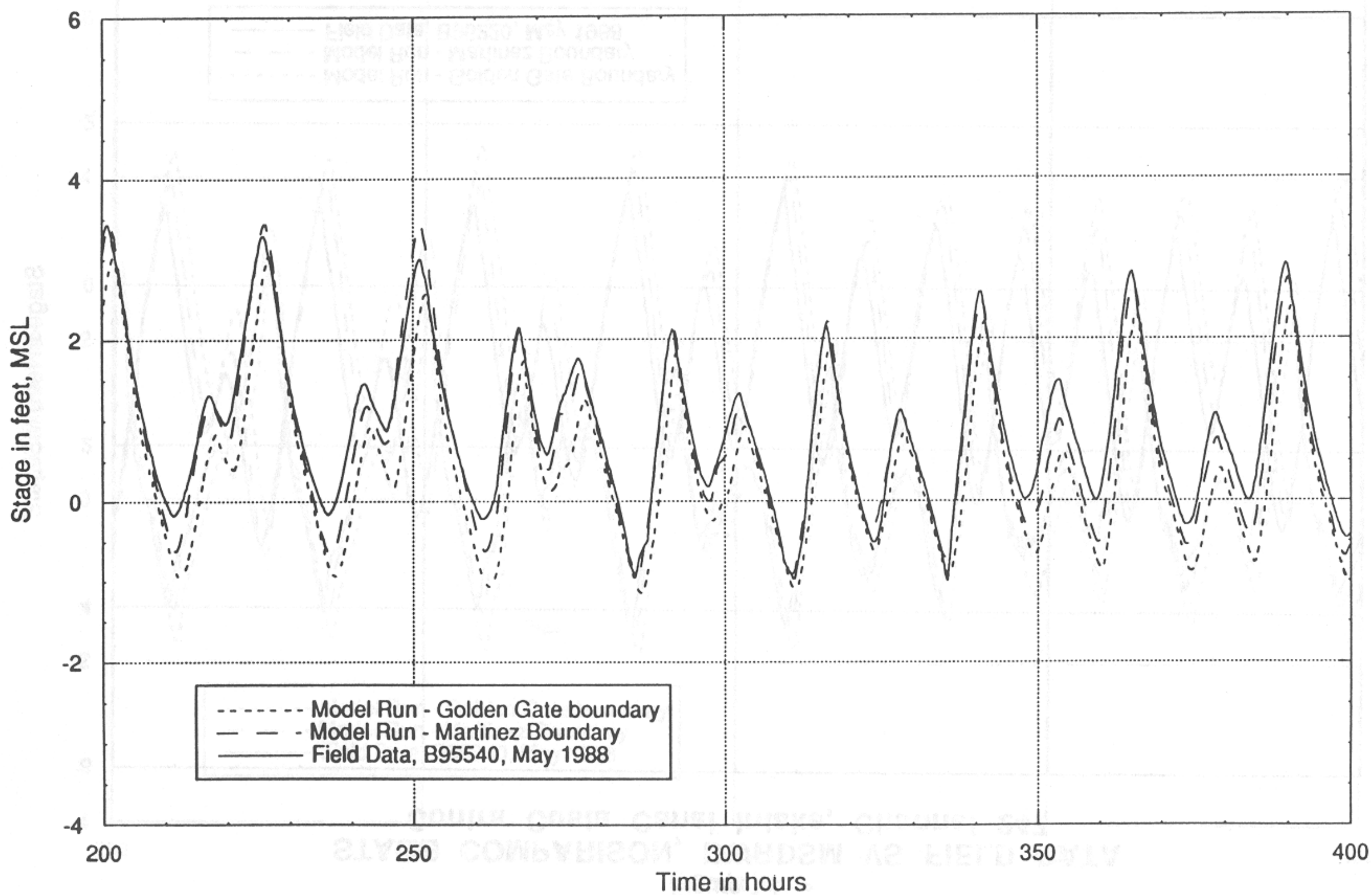


Figure 1-5

STAGE COMPARISON, DWRDSM VS FIELD DATA
Contra Costa Canal Intake, Channel 247

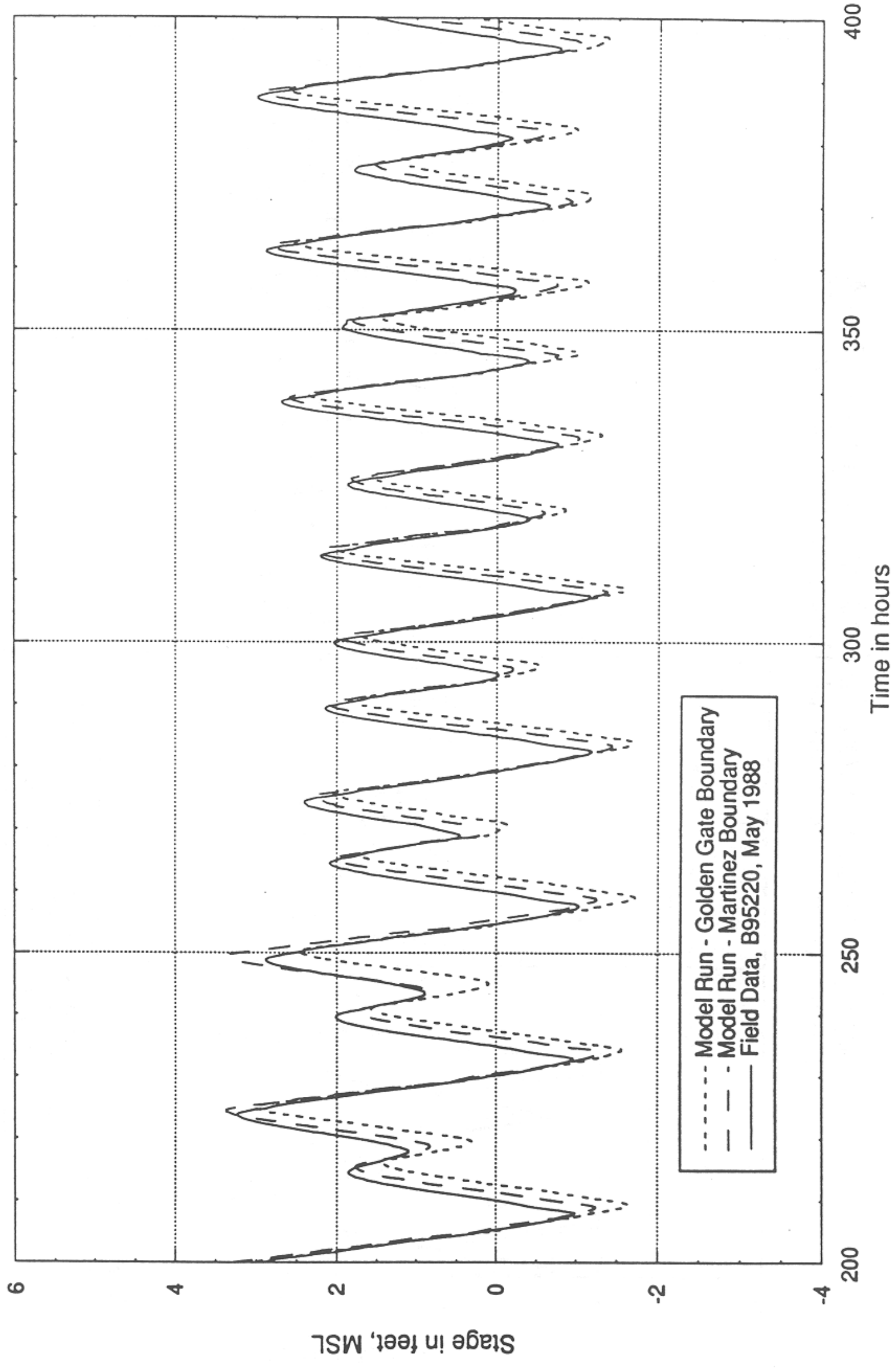


Figure 1-6

STAGE COMPARISON, DWRDSM VS FIELD DATA
Old River near Clifton Court Forebay, Channel 82

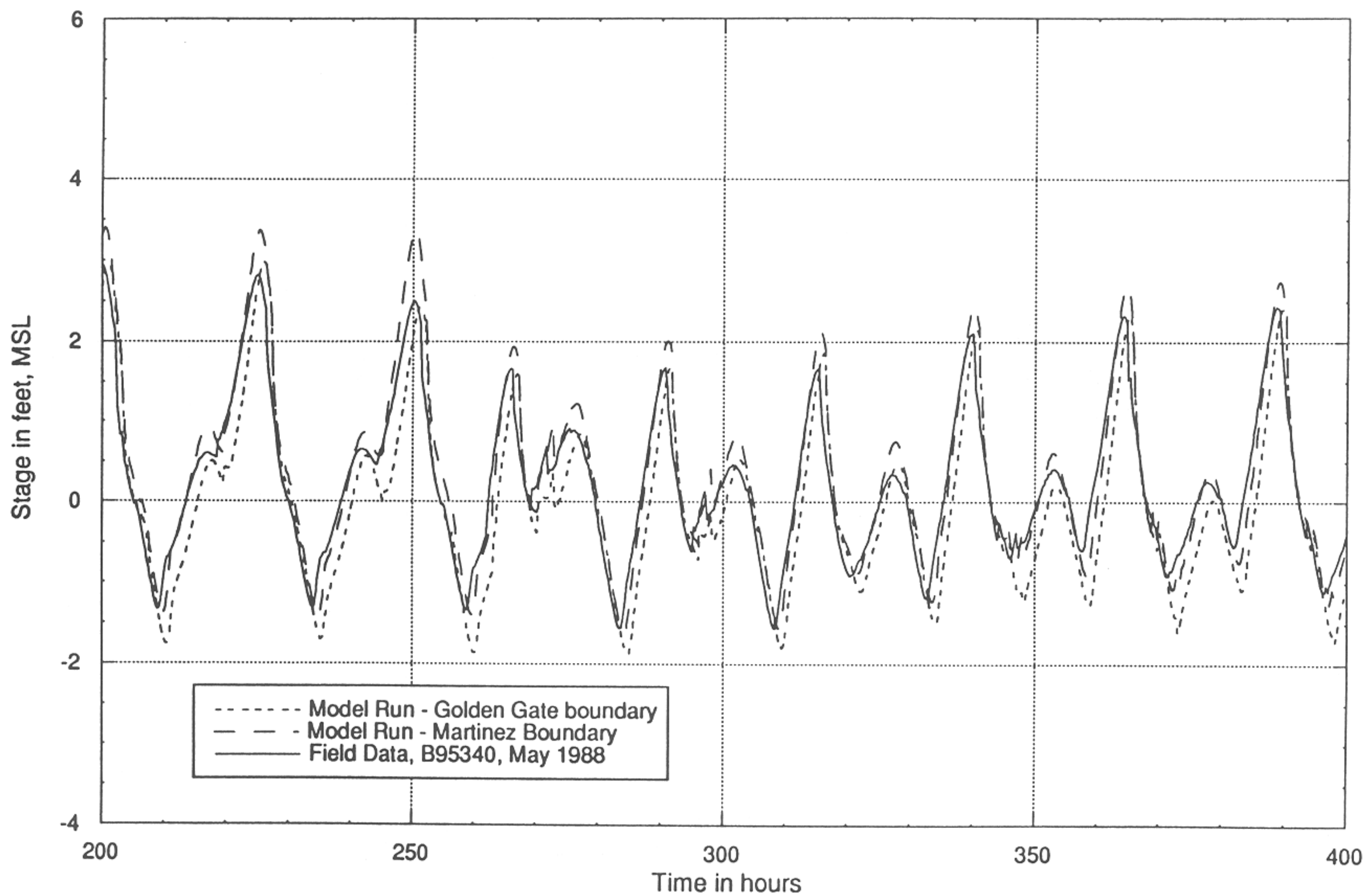
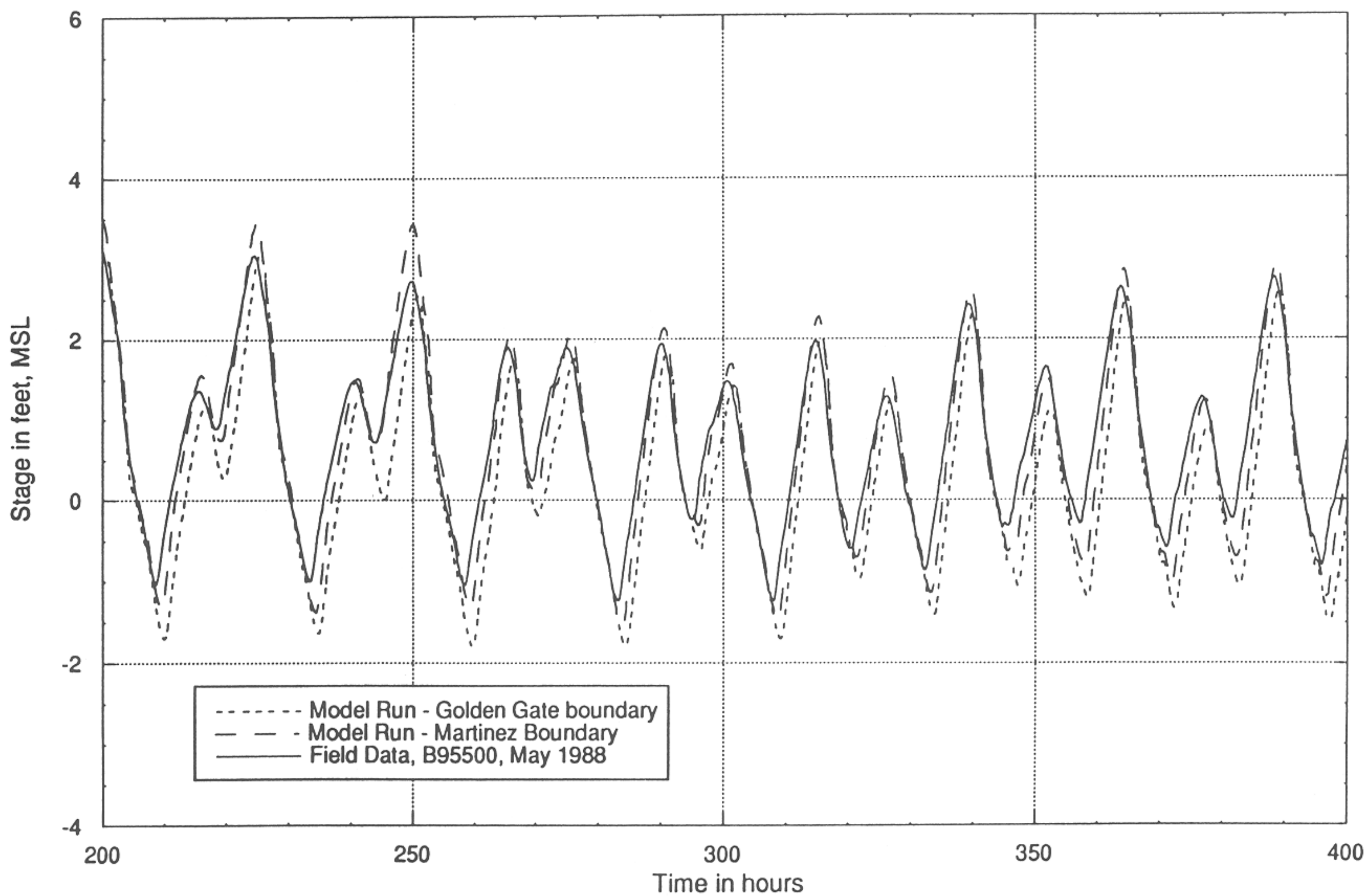


Figure 1-7

STAGE COMPARISON, DWRDSM VS FIELD DATA
Middle River near Barrier, Channel 134



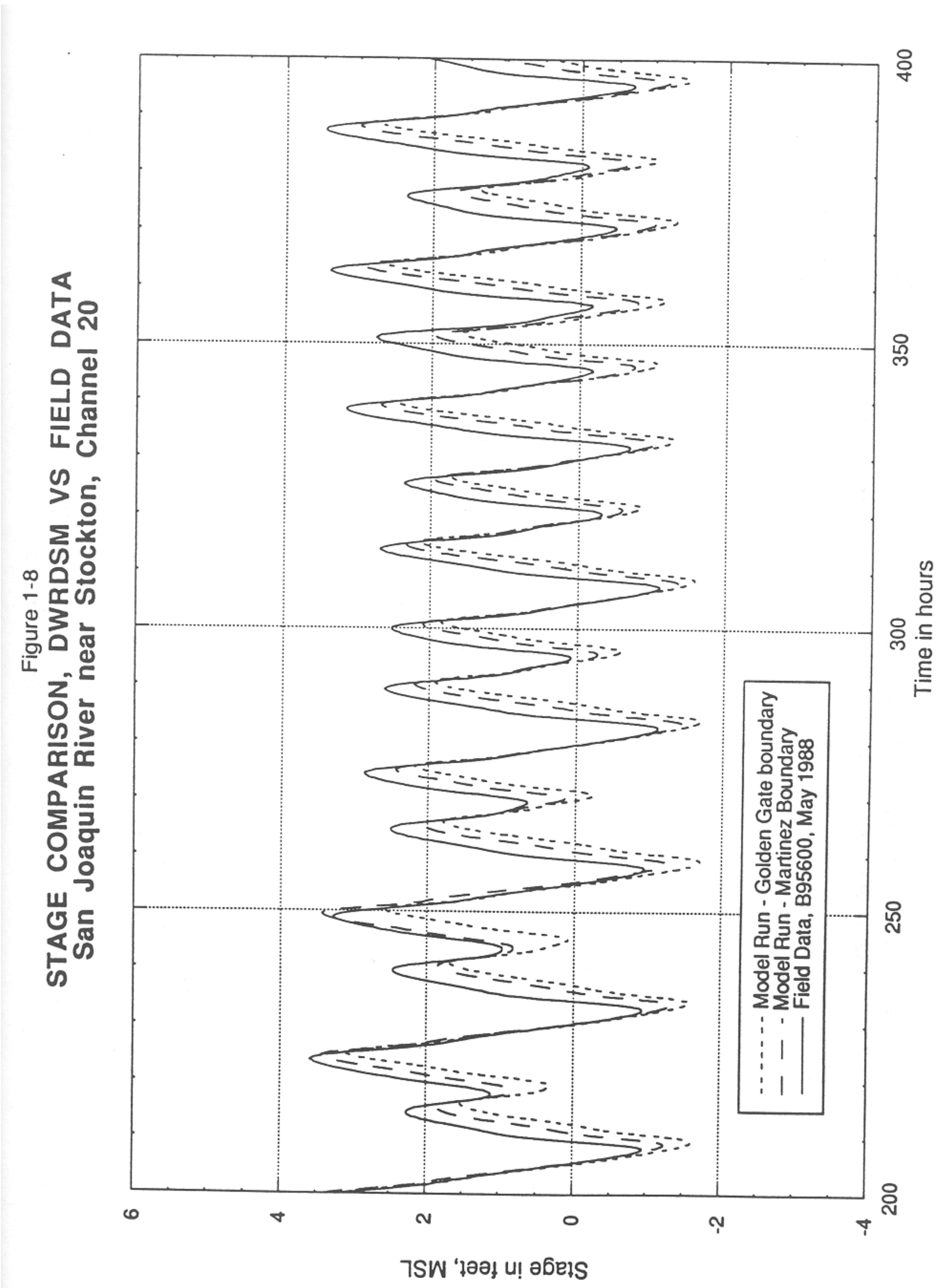


Figure 1-8
STAGE COMPARISON, DWRDSM VS FIELD DATA
San Joaquin River near Stockton, Channel 20
Stage in feet, MSL
6
4
2
0
-2
-4
200
250
300
350
400
Time in hours
Model Run - Golden Gate boundary
Model Run - Martinez Boundary
Field Data, B95600, May 1988

Figure 1-9

VELOCITY COMPARISON, DWRDSM VS FIELD DATA
San Joaquin River near Stockton, Channel 13

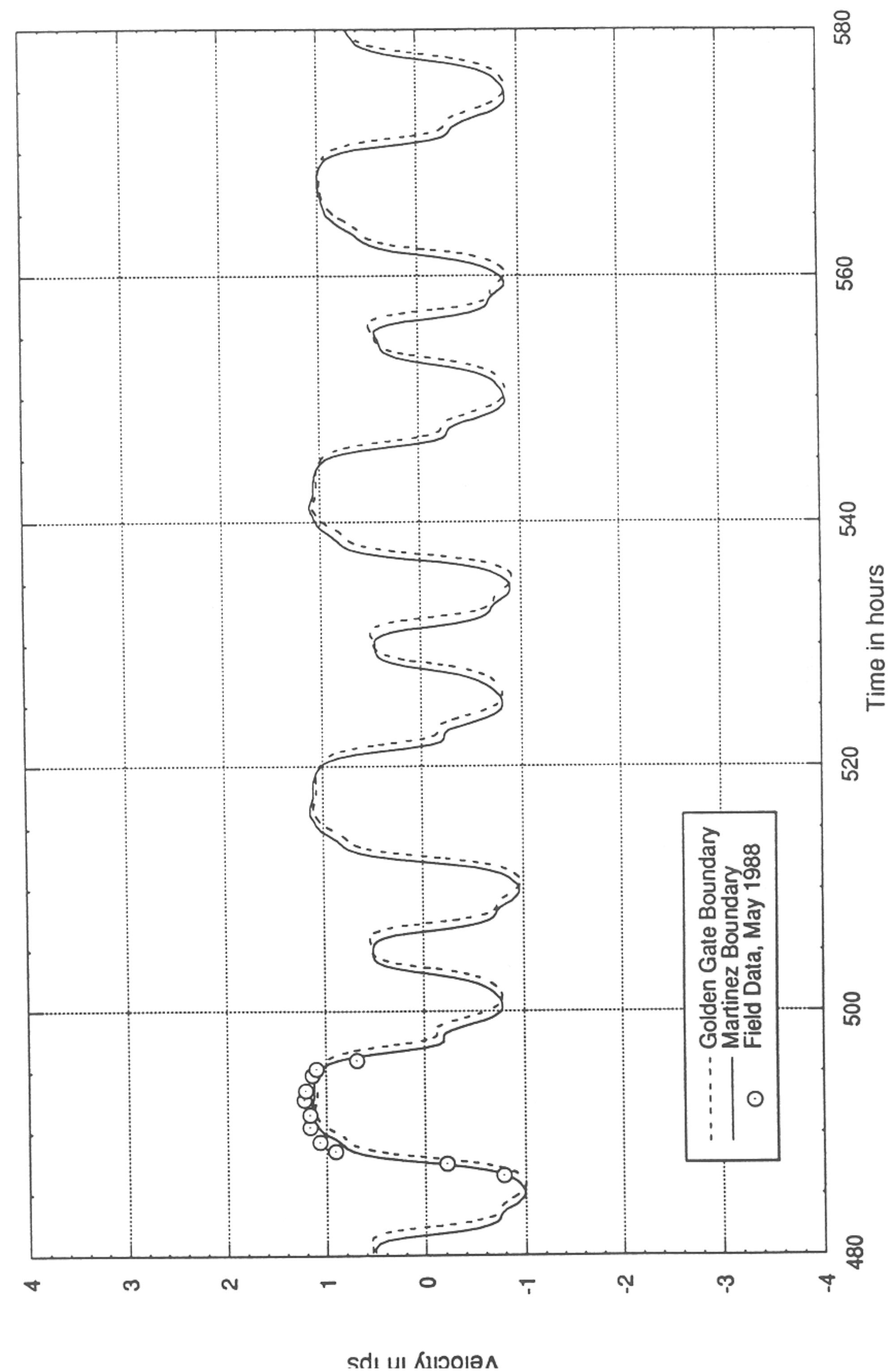


Figure 1-10

VELOCITY COMPARISON, DWRDSM VS FIELD DATA
San Joaquin River near Jersey Point, Channel 49

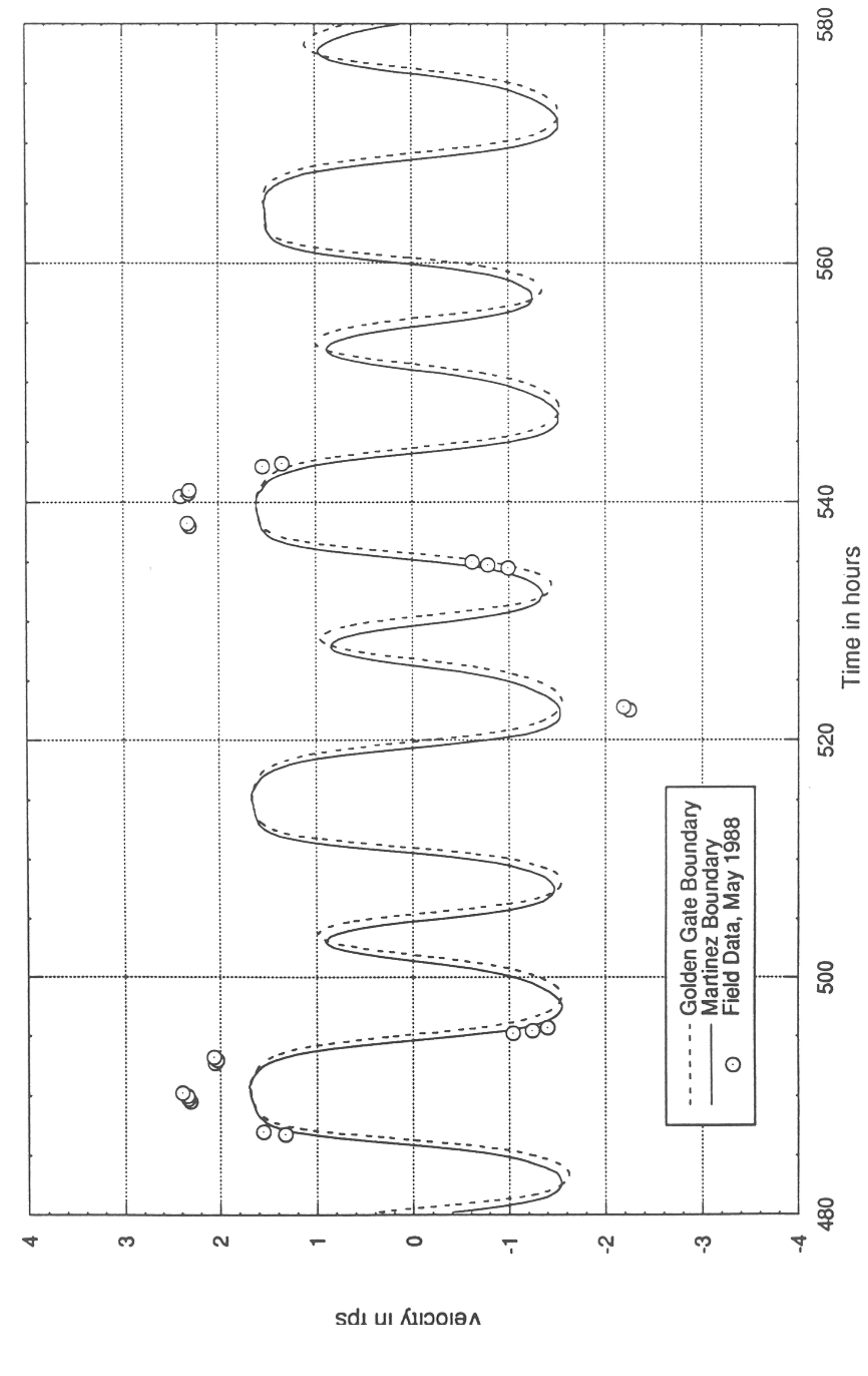


Figure 1-11
VELOCITY COMPARISON, DWRDSM VS FIELD DATA
Old River near Tracy Road, Channel 71

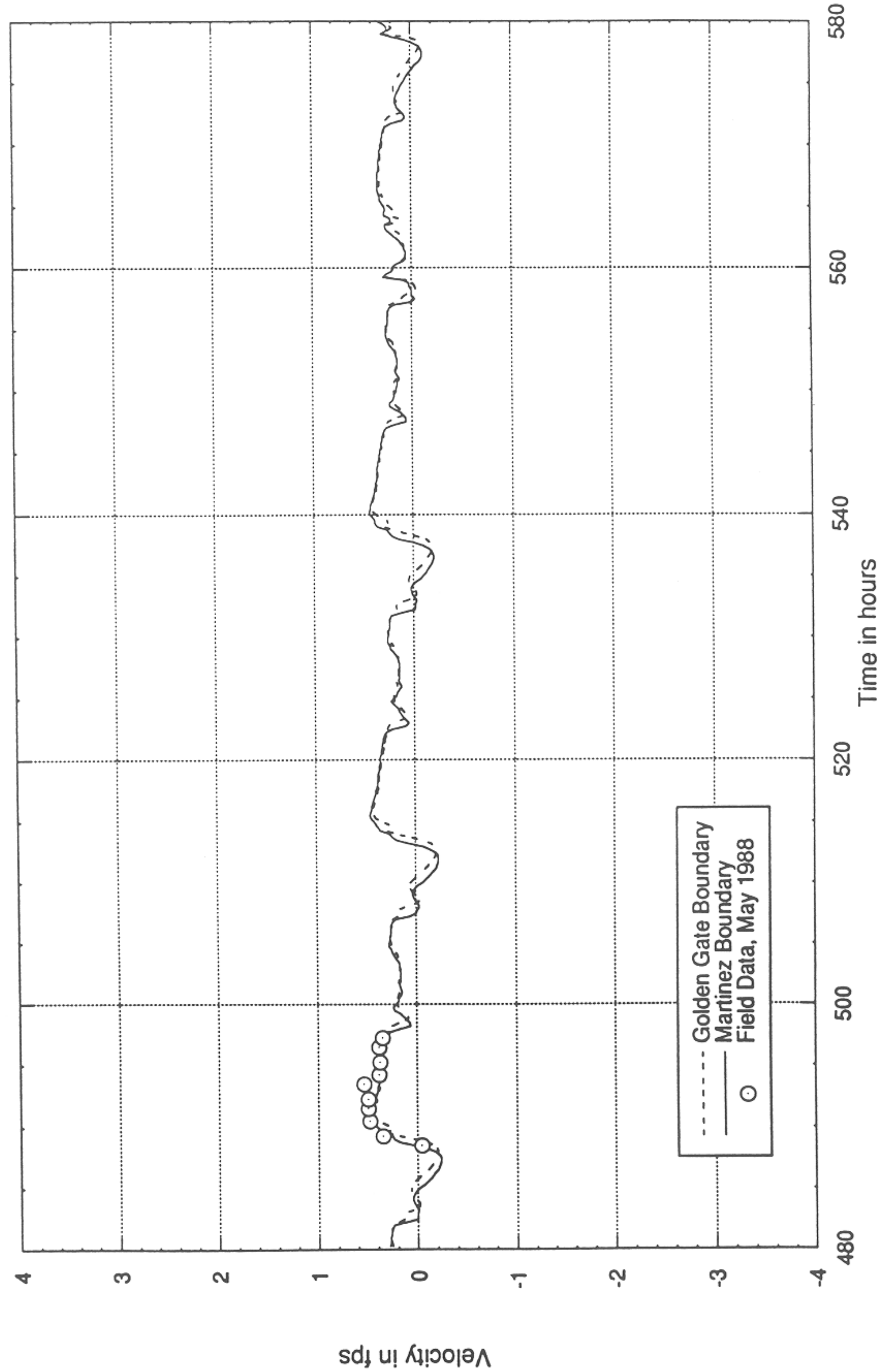


Figure 1-12

VELOCITY COMPARISON, DWRDSM VS FIELD DATA
Sacramento River near Decker Island, Channel 434

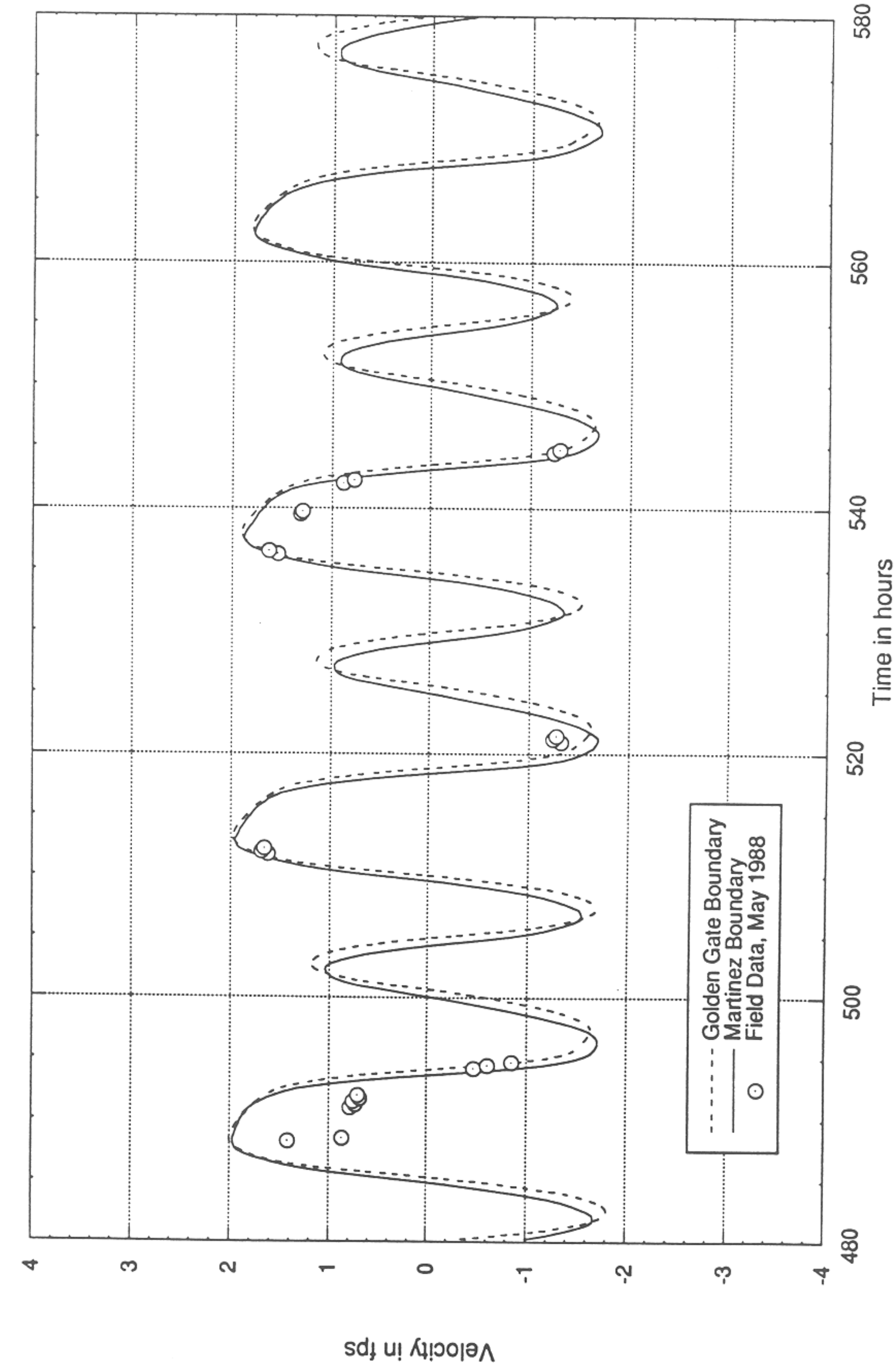


Figure 1-13

FLOW COMPARISON, DWRDSM VS FIELD DATA
San Joaquin River near Stockton, Channel 13

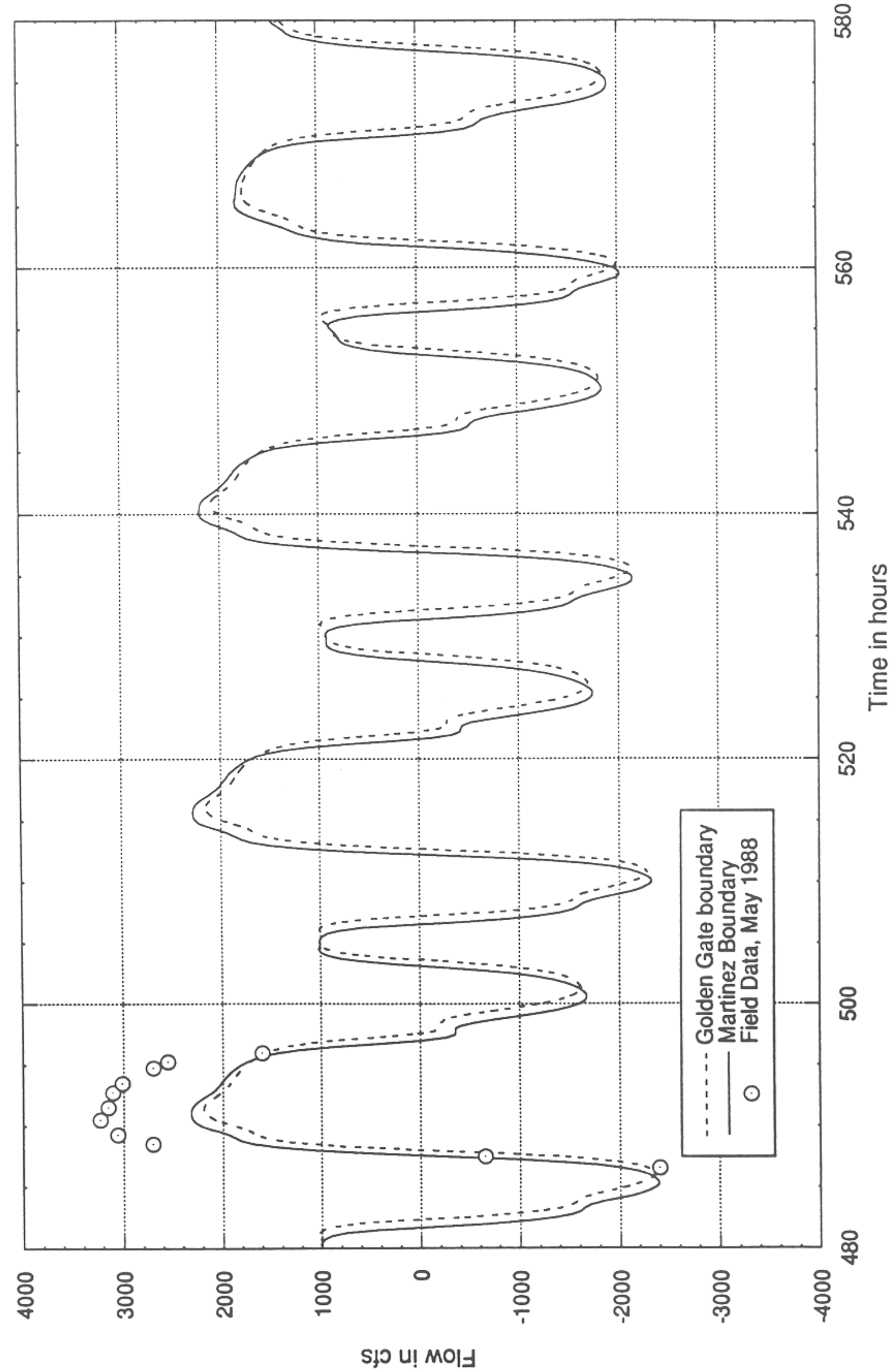


Figure 1-14

FLOW COMPARISON, DWRDSM VS FIELD DATA
San Joaquin River near Jersey Point, Channel 49

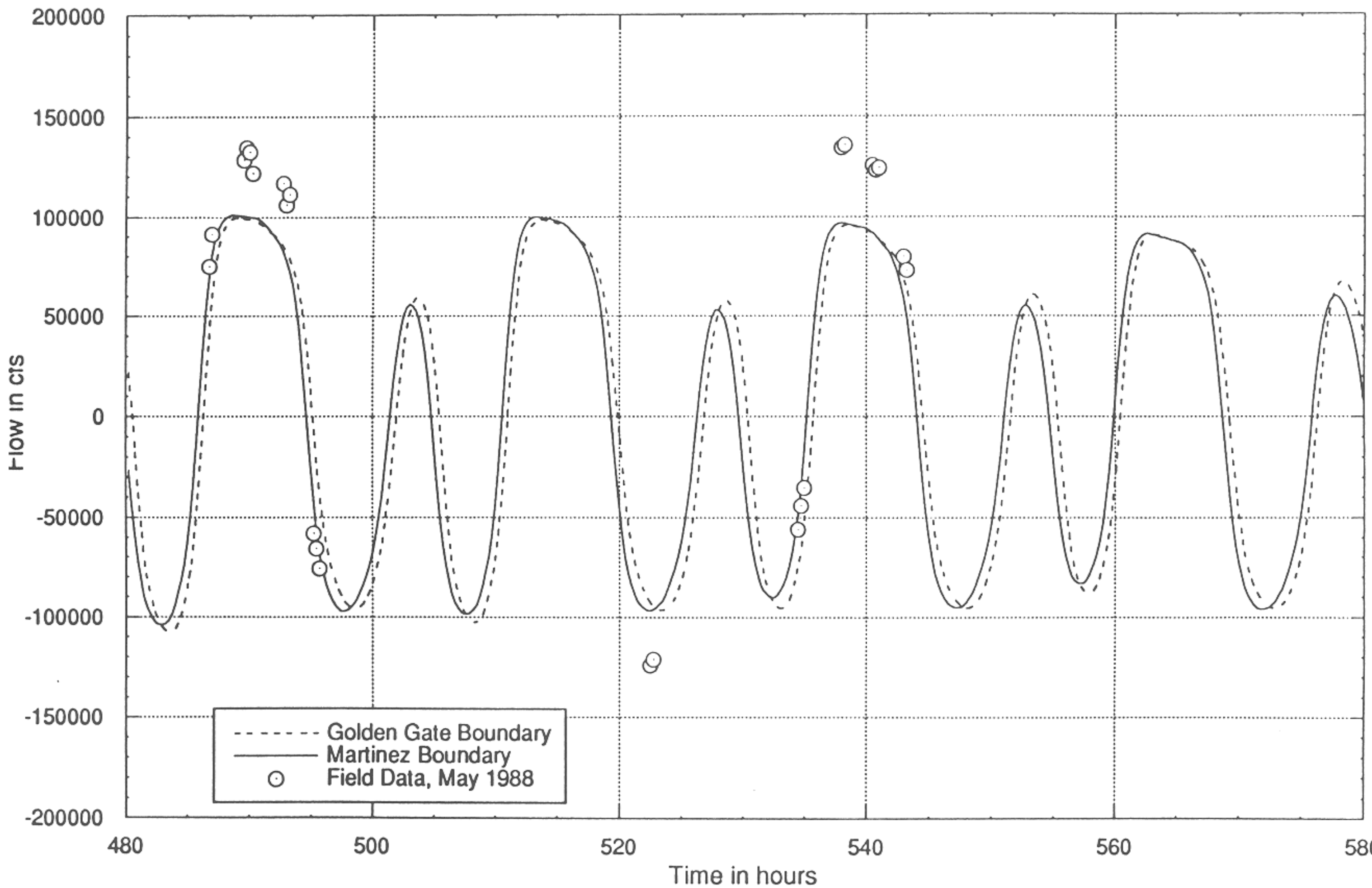


Figure 1-15

FLOW COMPARISON, DWRDSM VS FIELD DATA
Old River near Tracy Road, Channel 71

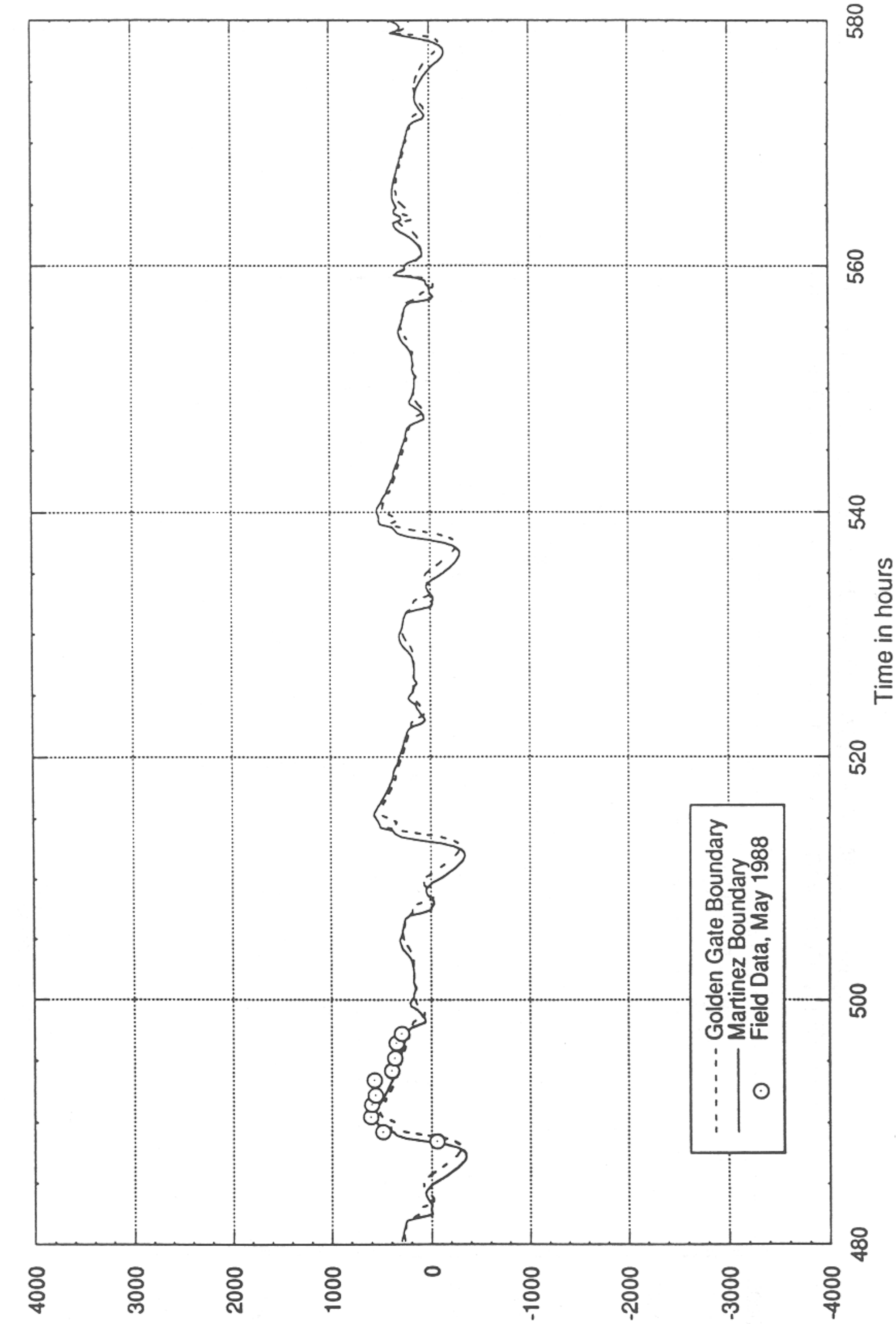


Figure 1-16

FLOW COMPARISON, DWRDSM VS FIELD DATA
Sacramento River near Decker Island, Channel 434

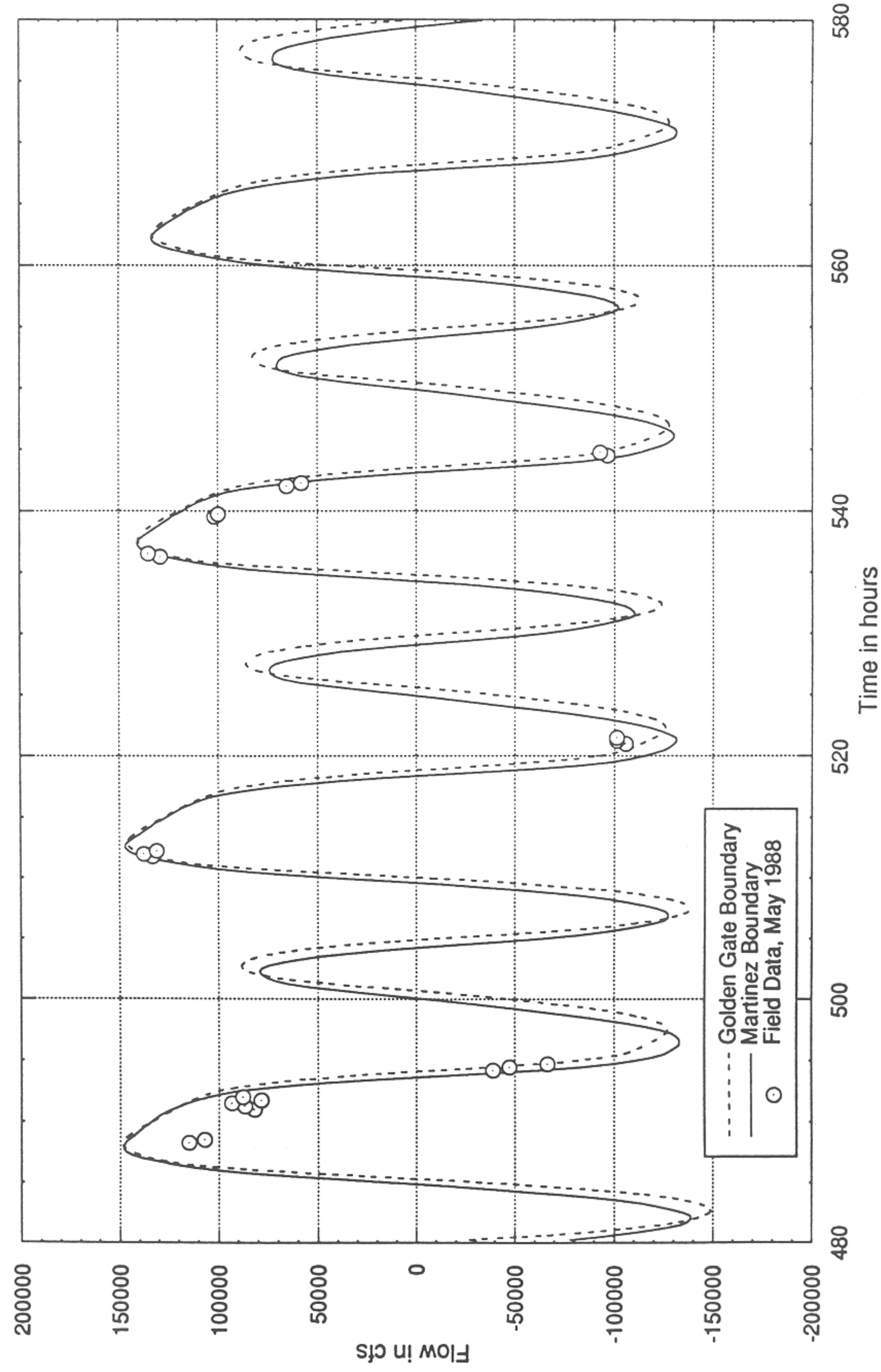
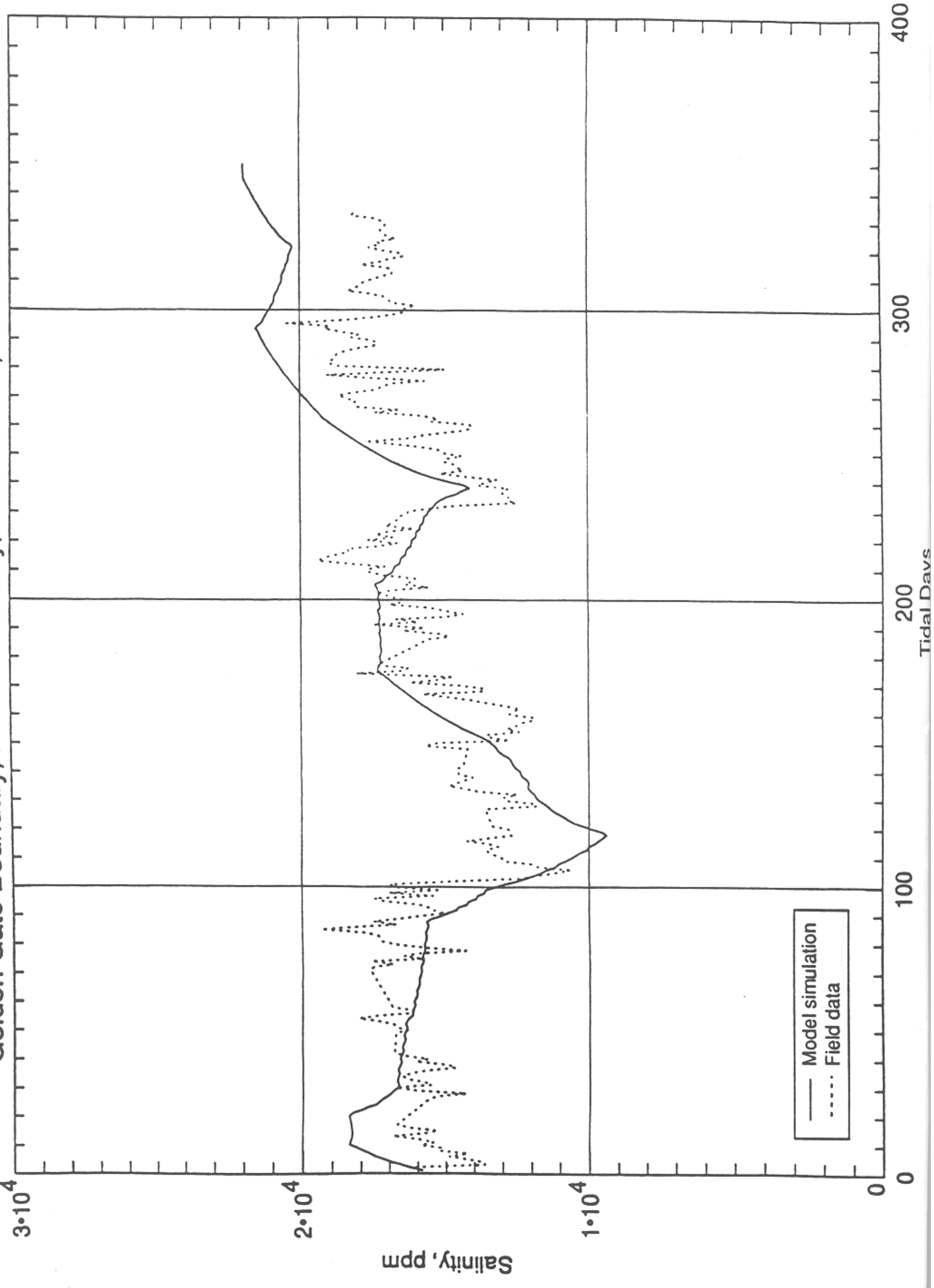


Figure 1-17

Golden Gate Boundary, Martinez Salinity, Channel 441, Water Year 1990



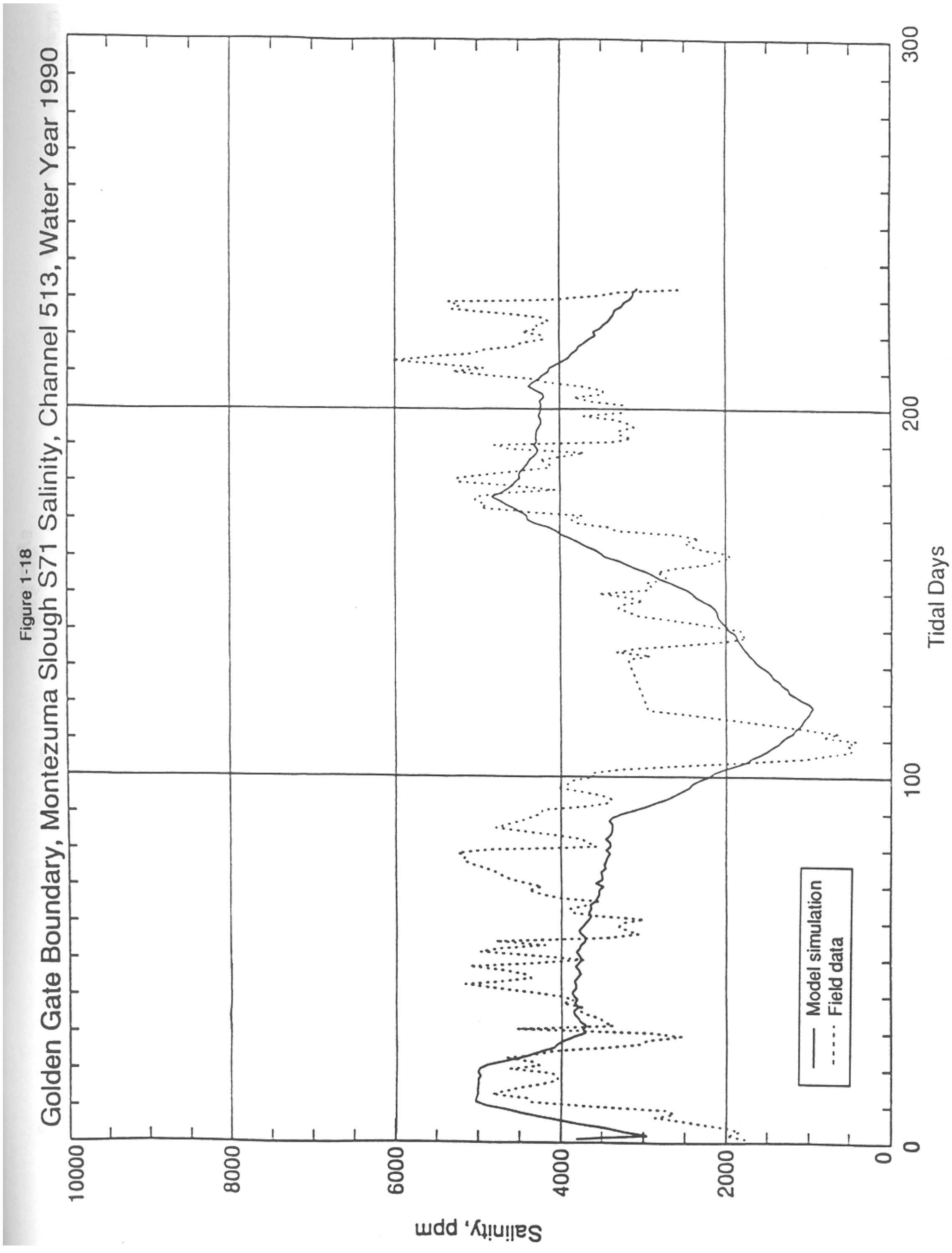


Figure 1-18
Golden Gate Boundary, Montezuma Slough S71 Salinity, Channel 513, Water Year 1990
Salinity, ppm
10000
8000
6000
4000
2000
0
0
100
200
300
Tidal Days
Model simulation
Field data

Figure 1-19

Golden Gate Boundary, S72 Salinity, Channel 530, Water Year 1990

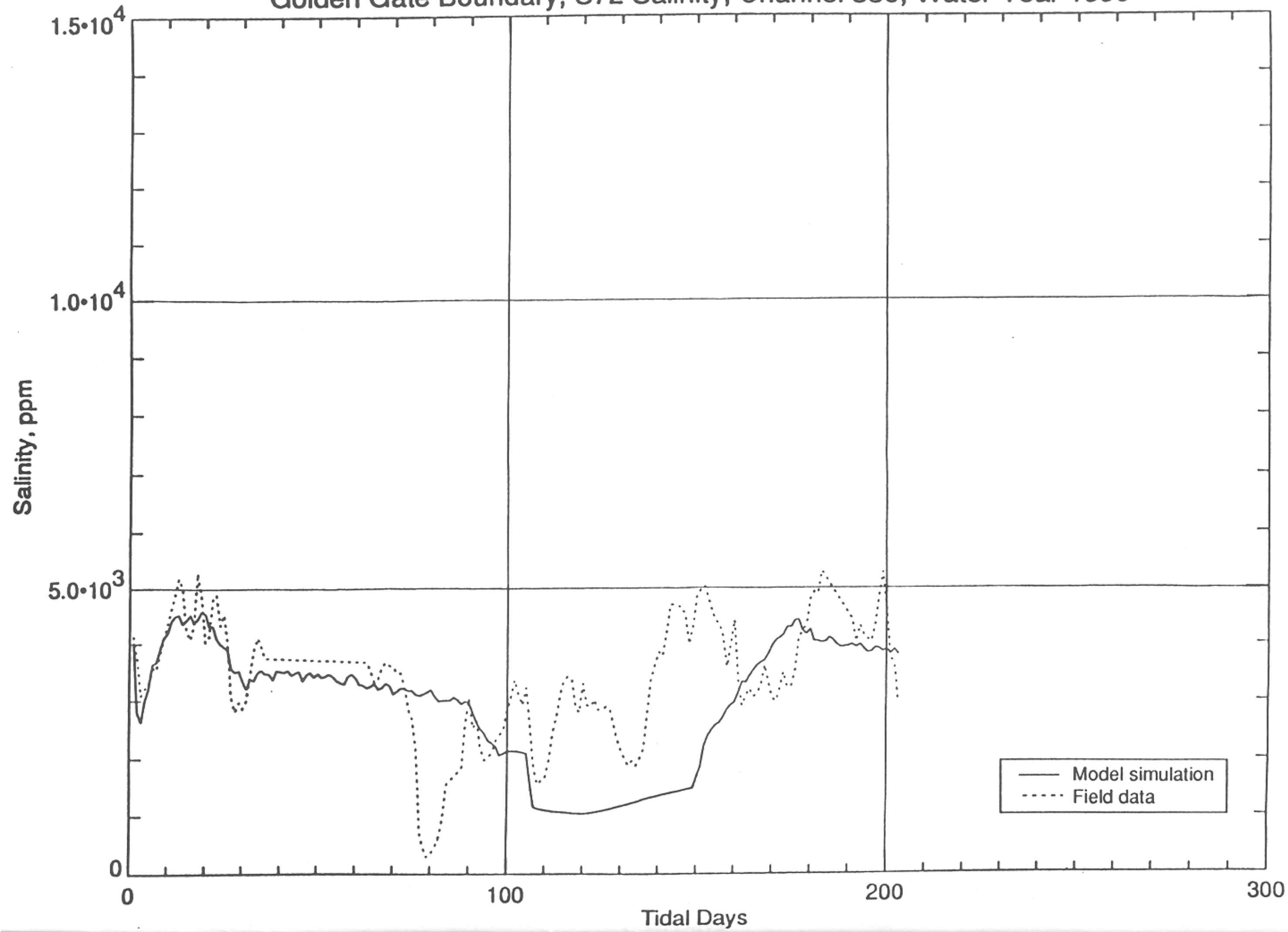
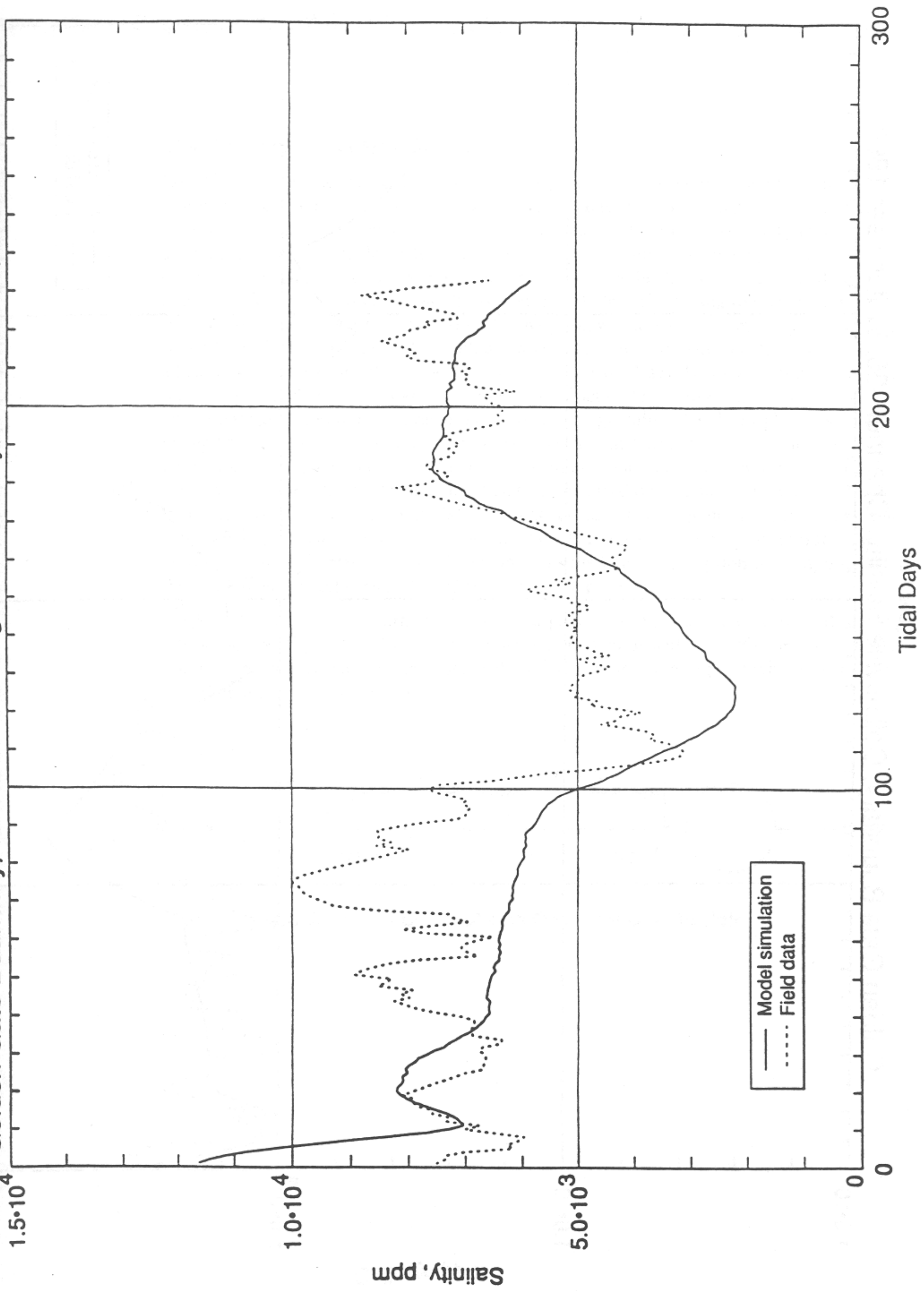


Figure 1-20

Golden Gate Boundary, Montezuma Slough S54 Salinity, Channel 522, Water Year 1990



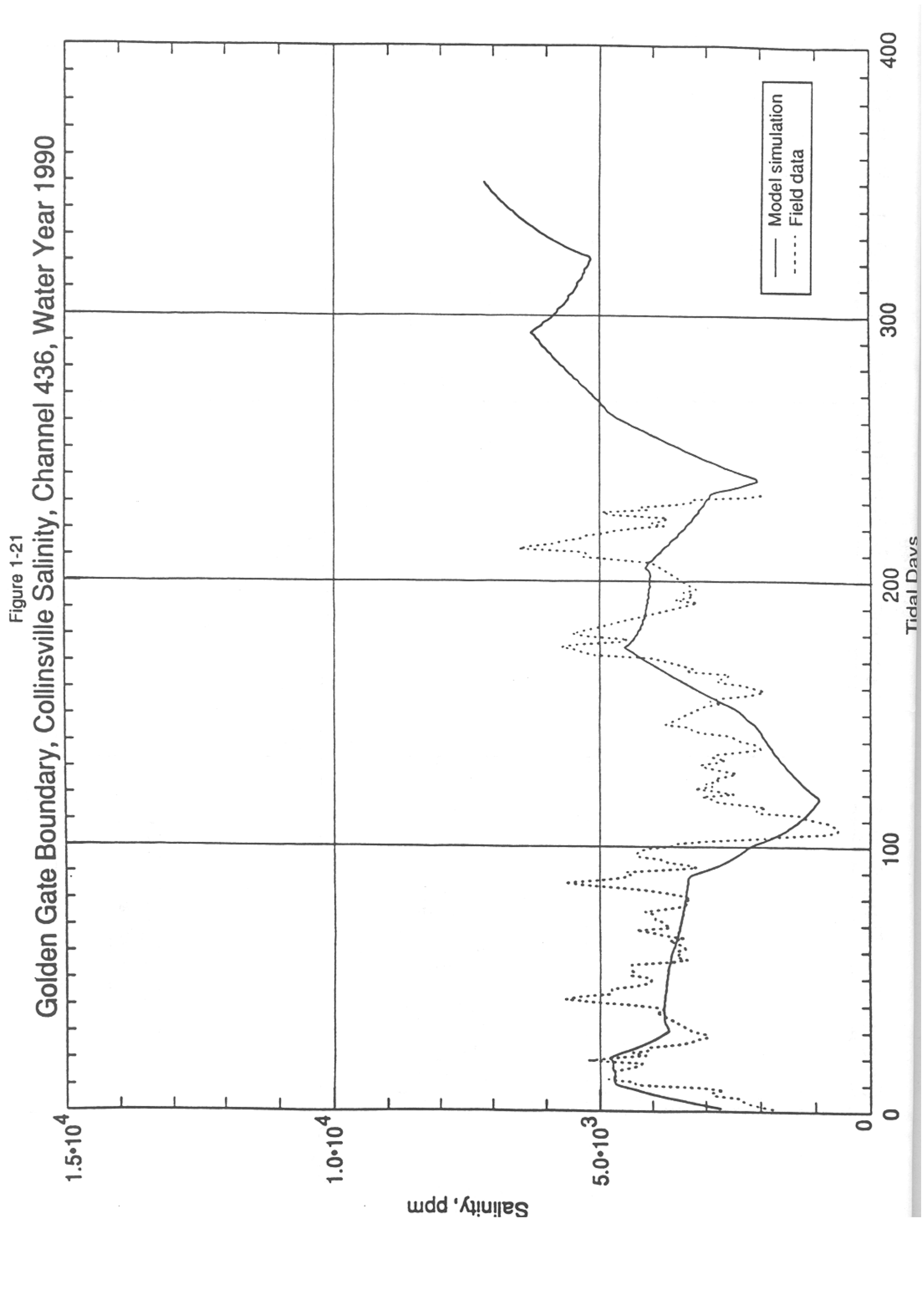


Figure 1-21
Golden Gate Boundary, Collinsville Salinity, Channel 436, Water Year 1990

Modifications to the Flow Model

DWRFLO solves the momentum and continuity equations using an explicit technique, which is based on the method of characteristics. Due to the explicit nature of this method, continuity is enforced at junctions, but within a channel it is maintained only in an approximate sense. This leads to numerical leakage (or sometimes mass gain) in various channels, the magnitude of which may be small for a single channel but could add up to a considerable amount when accumulated over the whole Delta during the simulation (about 8 percent of the net delta outflow). An option was available in the original version of the DWRDSM, called the "Leak Plug", where the amount which was leaked would be added to the system, and the model is run for another tidal day. However, after this cycle, there is still some leakage (about 1 to 3 percent of net delta outflow) caused by the additional flow. A system was developed two years ago called the "Multiple Leak Plug", where the system goes through successive cycles, and during each cycle the leaked amount is added back to the system. The user either requests a certain number of Leak Plus cycles, or lets the model decide when to stop, based on a certain tolerance for the leakage amount (currently set at 100 cfs). Leakage can only be quantified for steady-state runs, where the change in storage in one tidal cycle is zero. For nonrepeating tides, the amount of leakage cannot be calculated, and thus the Leak-Plug option is not applicable; therefore these model runs suffer from this leakage problem.

DWRDSM was modified further by making adjustments to the calculated stage at the interior nodes. Figure 1-22 shows a rectangular channel of width B with one interior grid point. The prime (') notation indicates values at the future time step, which are computed using the method of characteristics.

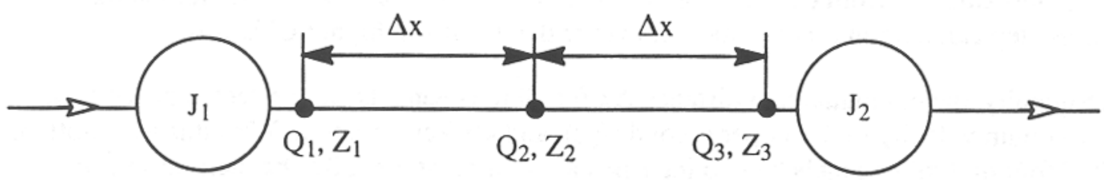


Figure 1.22: A Typical Channel with One Interior Grid Point.

The change of volume in one time step can be found two different ways:

1) Actual change in storage (trapezoidal rule)

$$\Delta V = \left[\left(Z_3^{'} + 2Z_2^{'} + Z_1^{'}\right) - \left(Z_3 + 2Z_2 + Z_1\right)\right] * B * \frac{\Delta x}{2}$$

2) Flow in minus flow out

$$\Delta V = \left[\left(Q_1 + Q_1^{'}\right) - \left(Q_3 + Q_3^{'}\right)\right] * \frac{\Delta t}{2}$$

These two values should theoretically be equal. However they generally are not, thus creating a leakage. To eliminate leakage in this channel, he value of Z2' is adjusted by forcing these two expressions to be equal, leading to one equation one unknown. Test results indicate that the small amount of correction for stage is usually less than 0.001 percent; however, this small modification results in elimination of leakage in this channel.

For channels with more than one intermediate grid point, the adjustments are done for the computed stage at all the intermediate points in the same proportion. For channels with no intermediate points, no adjustment can be made, and thus the leakage associated with them cannot be eliminated. Thus to reduce leakage, it would be desirable for force all channels to have an intermediate grid point. However, test results showed that some short channels suffered from Courant condition violation even for small flows. Reducing the time-step can help in this situation, however that results in higher CPU time.

Originally, the computational distance Δx for all the channels were selected based on a maximum velocity of 3 feet per second (fps), and 40 feet elevation. With this assumption, 202 (out of 496) channels had no intermediate grid point, i.e. 202 channels still have leakage problems. With an adjustment in the formula, the number of channels with no intermediate grid point was reduced to 60. This resulted in much lower leakage. Most test runs indicate that a leak-plug cycle may not even be necessary. The side-effect of making this adjustment is that the model has a higher chance of violating Courant condition. Test runs show that with the above adjustments, the model can handle up to about 50,000 cfs net delta outflow. To remedy this situation, instead of interrupting the model when a Courant condition violation was detected, the model is restarted, and the computational distance Δx is recalculated based on a maximum velocity of 5 fps. With this adjustment, the number of channels with no intermediate grid point is increased to 90. If the model still fails due to Courant condition violation, a final re-adjustment is performed based on a maximum velocity of 8 fps, increasing the number of channels with no intermediate grid point to 163. Previously, in a long-term modeling study, say a 20-year run, the user had to continuously keep track of the run. The remedy available to handle a Courant condition violation was to either reduce the time-step, or artificially increase the depth around the "problem" area. With the new code, the model makes all the necessary adjustments and restarts automatically. In addition the new code has a much better leakage characteristics.